hydrolysis. (See Table 2). Partial hydrolysis was found in all stations of the Squaw Harbor and Pelee Island regions, and in 2 stations of Terwilliger's Pond. Evidently the organisms capable of changing starch so as to be usable by other living organisms are quite prevalent. In 25 stations the hydrolysis was attended by a butyric acid odor. (See Table 2).

The production of hydrogen sulphide varied from strong production in 1 day to none in 10 days. (See Table 2). Even in a particular region certain stations revealed strong production while nearby stations showed none. The production

TABLE 4

DECOMPOSITION OF MAYFLIES

SAMPLE NUMBER	TEMPERATURE	DECOMPOSITION	
		Started	Completed*
A1	55° C.	Slight (22 days)	Complete (60 days)
A2	55° C.	Slight (15 days)	Moderate (60 days)
B1	37° C.	Slight (5 days)	Complete (29 days)
B2	37° C.	Slight (7 days)	Complete (37 days)
C1	20° C.	Slight (7 days)	Complete (29 days)
C2	20° C.	Very slight (14 days)	Slight (60 days)

* Completed or when experiment was terminated.

In the above samples, mayflies were placed below the mud in sample numbers A1, B1, and C1, while the mayflies were placed upon the surface of the water in sample numbers A2, B2, and C2.

TABLE 5

DECOMPOSITION OF GREEN ALGAE

SAMPLE NUMBER	TEMPERATURE	DECOMPOSITION	
		Started	Completed*
D3	55° C.	Slight (4 days)	Slight (64 days)
D4	55° C.	Slight (4 days)	Slight (64 days)
E3	37° C.	Slight (4 days)	Complete (20 days)
E4	37° C.	Slight (4 days)	Complete (21 days)
F3	20° C.	Slight (29 days)	Complete (45 days)
F4	20° C.	Slight (35 days)	Complete (60 days)

* Complete, or when experiment was terminated.

of indole also varied in a similar manner. The production of gas in lactose broth was pronounced in a great majority of stations in 24 or 48 hours except in the Pelee Island region. (See Table 2). In the latter region a maximum of ten per cent of gas was produced in 48 hours. In a few stations in Haunck's Pond a slight quantity of gas was produced in 24 hours but a large quantity was formed after 48 hour incubation. These data do not necessarily mean pollution by intestinal organisms because they were not traced on differential media to prove their identity. Other types of aquatic organisms might also produce gas in lactose broth.

A study of data in Table 3 showing the average number of colonies (in millions per gram of soil) on agar plates reveals (1) that the averages for the stations in Lake Erie proper are usually below the average for other regions; (2) that the average for the Put-in-Bay Harbor region was high, particularly at 37° C. This is to be expected when the pollution problem is taken into consideration. Similar

data were found in the Portage River area. Counts in the same station varied from time to time as repeated sampling revealed. The relative counts in all stations evidently were influenced by such factors as hydrogen ion concentrations, the quantity and quality of foods available, the amount of available oxygen, the presence of other micro-organisms which might live symbiotically or antagonistically with those being tested.

The experiments dealing with the decomposition of mayflies (Table 4) show that the optimum temperature for the complete as well as the most rapid decomposition was 37° C. (or slightly below as suggested by sample CI). When a temperature of 20° C. was satisfactory the mayflies apparently had to be covered with a coat of mud in order to expedite and complete the decomposition process. However, when covered too deeply the mayflies filled with gas and "popped" out of the mud before decomposition took place.

The decomposition of green algae (Table 5) also took place best at 37° C., although complete decomposition did occur at 20° C. but in a greater period of

TABLE 6

RATES OF DECOMPOSITION OF MAYFLIES, GREEN ALGAE AND CERATOPHYLLUM

(As Determined by Gas Production)

	37° C.		20° C.	
	Gas in Tube	Decomposition	Gas in Tube	Decomposition
I. Control	None (34 days)		None (34 days)	
II. Ceratophyllum	Slight (5 days) Full (10 days)	Slight (31 days)	None (34 days)	None (34 days)
III. Green Algae	Slight (5 days) Full (10 days)	Complete (18 days)	None (34 days)	Slight (34 days)
IV. Mayflies	Much (5 days) Full (8 days)	Complete (27 days)	None (34 days)	None (34 days)

time. A slight degree of decomposition occurred at 55° C. in 4 days but the amount of destruction did not advance beyond that point within 64 days at which time the experiments were concluded.

The rate of decomposition of mayflies, algae and hornwort (*Ceratophyllum*) as shown by gas production (See Table 6) also revealed the optimum temperature to be 37° C. In fact, at 20° C. incubations, no gas was produced in 34 days by any of the three materials tested. Only the algae were slightly decomposed in 34 days when incubated at 20° C. However, at 37° C. the production of gas was extensive and the decomposition was complete for the algae in 18 days and for the mayflies in 27 days. The *Ceratophyllum* decomposed only slightly in 31 days at 37° C. which might suggest its resistance to destruction by the quantity and quality of the particular micro-organisms present.

The decomposition of the plant and animal materials, if the temperature and other factors are satisfactory, occurs rather rapidly thus making available their constituents for use by future organisms. It would appear that the organisms responsible for optimum decomposition of the materials tested are those of animal origin because their optimum temperature was 37° C. The aquatic types of micro-organisms whose optimum temperatures are expected to be below 37° C. probably play a minor role in this phenomenon. This is also true for the thermophilic micro-organisms whose optimum temperature is 55° C. The presence in rather large numbers of micro-organisms whose optimum temperature is 37° C. as revealed by laboratory tests of the soil samples, undoubtedly substantiates this conclusion.

REFLECTIVITY OF THIN FILMS

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INTRODUCTION

The reflectivity of a smooth glass surface, when treated with a thin monolayer film, may be lessened, or, when treated with a multilayer film, may be increased for a given wave-length of light. The effect produced depends on the thickness and index of refraction of the film.

There are three methods of preparing a film of appropriate thickness on a glass surface. First, by treating the surface chemically. This method was first developed in the experiments of H. D. Taylor (5) in 1892 and the recent experiments of F. L. Jones and H. J. Homer (4). A thin film is formed by treating the glass with a weak acid which will dissolve the oxides from a thin layer but not affect the silica.

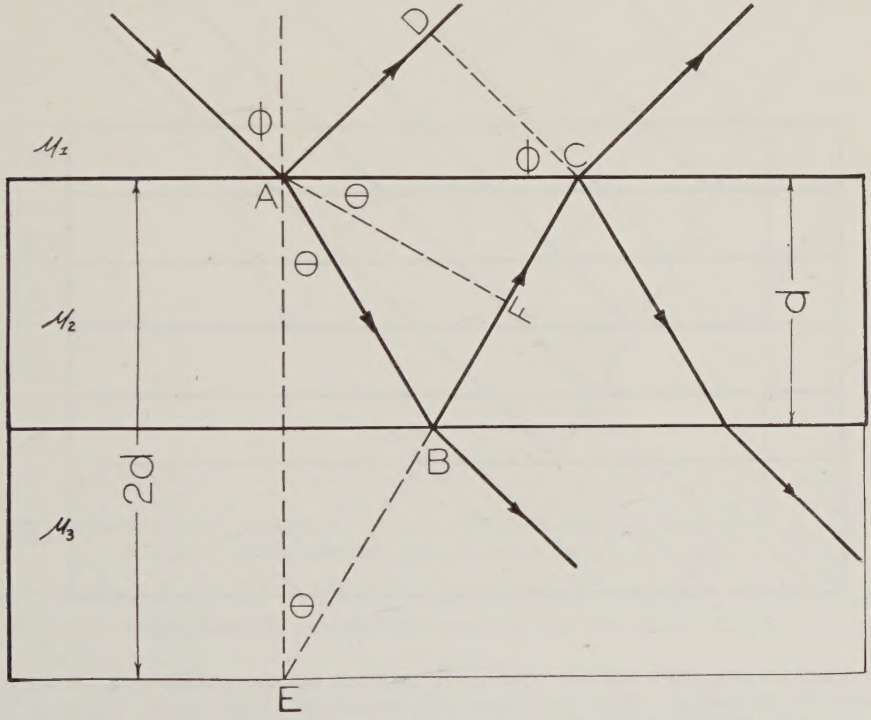

Fig. 1. A beam of light incident upon a film is partially reflected at A and partially refracted.

Secondly, by building up a film composed of successive applications of monomolecular layers of certain metallic soaps, a process originated by K. B. Blodgett (1). The third method, developed by Cartwright and Turner (2), is that of evaporating suitable metallic compounds in a high vacuum and allowing the condensate to deposit on the glass surface.

The efficiency of spectrometers, telescopes, interferometers, and other optical instruments is increased by treating the glass surfaces with thin films. The purpose of this investigation is to develop an apparatus and procedure of applying such thin films to glass surfaces. The method of evaporating metallic compounds in a high vacuum is chosen as the most practical for a small optical laboratory.

THEORY

The effects mentioned above depend upon the interference of light. A beam of light incident upon a film (Fig. 1) is partially reflected at A and partially refracted. The refracted ray is reflected at the surface between the film and the glass at B and emerges from the film at C. If the path difference of the two rays is any whole number of wave-lengths, they will reinforce each other or if the path difference is an odd number of half wave-lengths, they will interfere destructively. A general expression for the retardation of the ray emerging at C is $2\mu d \cos \theta + \delta_1 + \delta_2$, where μ is the index of refraction of the film, d is its thickness, θ is the angle of refraction, and the change in phase which might occur at the two surfaces due to the different indicies of refraction is represented by δ_1 and δ_2.

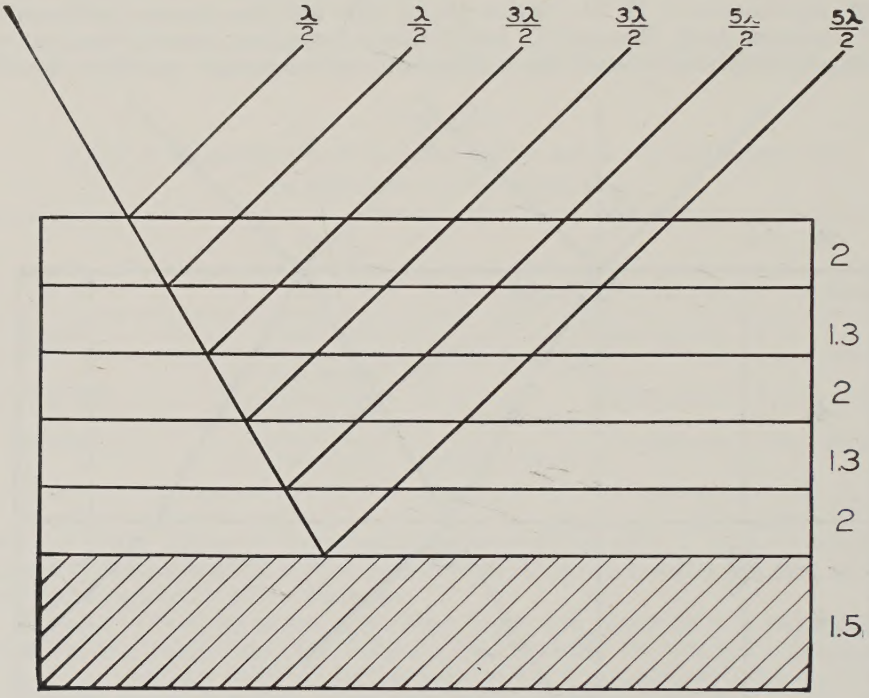

Fig. 2. A beam of light at normal incidence on the top surface.

In order to prepare a surface which will produce selective reflection for a given wave-length, multilayer films are deposited, composed of alternate layers of high and low index of refraction. Referring to Fig. 2, consider a beam of light at normal incidence to the top surface. Upon entering a medium more dense than air a change in phase of 180° occurs which can be represented as a path increase of ½ wave-length. The beam which is reflected from the second surface traverses the film twice but suffers no change in phase at this surface. If the films are ¼ of a given wave-length in thickness, then the path increase is ½ wave-length. The ray reflected at the third boundary traverses four thicknesses of the film and in addition suffers a change in phase making a path increase of ½ wave-lengths. If this is followed through for all the successive boundaries the emerging rays are in phase. The path difference is an integral number of whole wave-lengths, thus producing reinforcement for the given wave-length.

Two requirements must be met in order to produce a filmed surface of zero or nearly zero reflecting power. The monolayer film must be of such a thickness that

the path difference of the rays reflected from the air-film surface and the film-glass surface is an odd number of half wave-lengths and secondly the amplitudes of the rays reflected at the two surfaces must be equal.

The first condition is satisfied by depositing a film of ¼ wave-length optical thickness. The second requirement is satisfied, by choosing a film of proper index of refraction according to the following theory.

Fig. 3 shows the reflections which take place at the two surfaces. Let r_1 and r_2 equal the percent of the incident amplitude reflected at the air-film surface and the film-glass surface respectively. The per cent of the amplitude transmitted upon entering and leaving the film is represented by t and t' respectively. If the amplitude of the incident ray is a, then the amplitude of the light reflected from the air-film surface is ar_1. The amplitude of the light reflected from the film-glass surface is

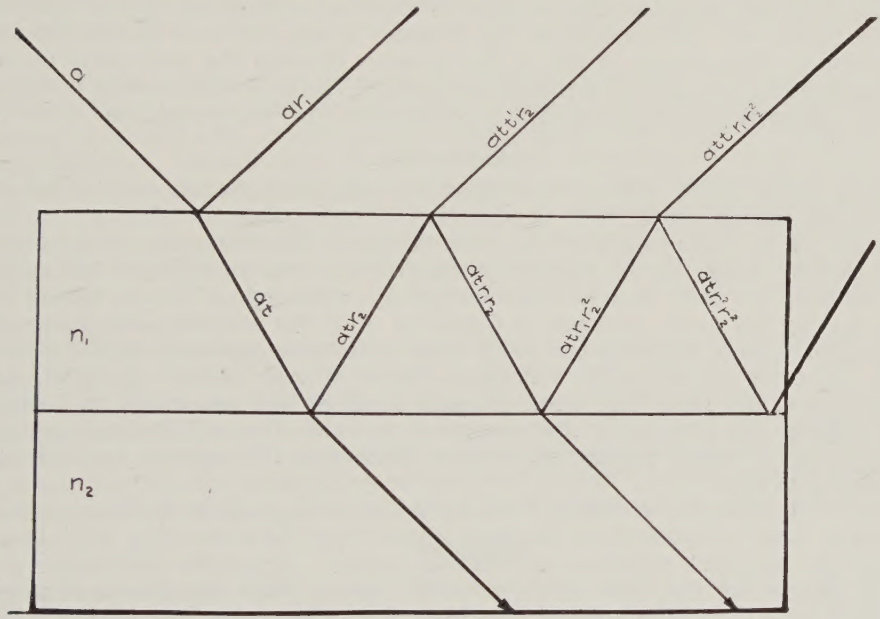

Fig. 3. Reflections which take place at the two surfaces.

the sum of all the rays due to the multiple reflections. The sum, R, of all these rays reflected at the film-glass surface is:

$$R = att'r_2 + att'r_1r_2^2 + att'r_1^2r_2^3 + att'r_1^3r_2^4 + \ldots\ldots$$
$$= att'r_2 (1 + r_1r_2 + r_1^2r_2^2 + r_1^3r_2^3 + \ldots\ldots)$$

The sum of the geometric series is $1/(1-r_1r_2)$. It can be shown (3) that $tt' = (1-r_1^2)$. Substituting these values:

$$R = a(1-r_1^2)r_2/(1-r_1r_2).$$

In order that the amplitudes be equal, R must equal ar_1. Putting $r_1 = r_2$ in the above expression, it follows that $R = ar_1$, and the second condition is fulfilled. Now $r_1 = (n_1-1)/(n_1+1)$ and $r_2 = (n_2-n_1)/(n_2-n_1)$ for normal incidence (6), where n_1 and n_2 are the indicies of refraction of the film and glass respectively.

Equating these epxressions and solving for n_1:

$$(n_1—1) / (n+1) = (n_2—n_1) / (n_2=n_1)$$
$$n_1 = \sqrt{n_2}$$

Thus the index of refraction of the film must equal the square root of the index of the glass if the amplitudes are to be exactly equal.

This demand upon the index of refraction of the film is rather severe since the lower limit of indicies of materials is about that of water, namely, 1.33. Metallic flourides are among the substances of lowest index and also are evaporated readily. The index of the film can be lowered to the desired value by allowing the evaporation to take place in a poor vacuum but this is done at the expense of the mechanical strength of the film.

APPARATUS

The vacuum system consists of a circular steel plate and a bell jar ground to fit the contour of the plate which is ¾ inches thick and 18 inches in diameter. The jar is evacuated through a one inch opening in the plate by a single stage oil diffusion pump backed by a Cenco Megavac vacuum pump. The metallic compounds are vaporized in small electric furnaces, which are wound in the form of a helix of 20 mil. tungsten wire sealed with alundum cement, and baked out thoroughly before use. The current for the furnaces is supplied by a 10-volt 500 watt transformer. The current is led to the furnaces through the steel plate by two insulated electrodes and one grounded electrode. The glass specimen to be coated is held horizontally from an upright post threaded into the base plate.

PROCEDURE

Glass plates giving almost monochromatic reflection are prepared as follows: First a film having a high index of refraction is deposited on the glass surface to a thickness of ¼ wave-length of the color desired. The thickness of the film is controlled by observing the surface, continuing the evaporation until the surface first assumes the color desired when viewed by white light. Then a film of low index having the same thickness is deposited until the selected color reappears. Layers of alternate high and low index of refraction are deposited in this manner until the color is brilliantly reflected. Films of zinc sulfide ($n=2.00$) and cryolite ($n=1.36$) have very good physical qualities and are evaporated easily. Two furnaces, one containing the zinc sulfide and the other cryolite, are arranged so they can be heated alternately without destroying the vacuum for each new application of film.

For a low reflecting surface a monolayer film of magnesium fluoride, index of refraction 1.34, is deposited on the glass surface to a thickness of ¼ wave-length of the light for which minimum reflection is desired. Again the thickness is controlled by viewing the color of the reflected light. When the film is of proper thickness to produce interference in the blue, the surface takes on a brownish hue. As the thickness increases the spectral region of minimum reflectance travels toward the longer wave lengths. When the minimum is in the green the surface appears magenta and when it arrives in the red the color becomes blue.

For normal incidence the reflectance of a glass surface for monochromatic light can be reduced to a minimum of .4% by depositing the above mentioned film of magnesium fluoride. The reflectance of the untreated glass of index refraction 1.55 is about 4.4%. This is a reduction in reflection of 91%. In order to reduce the reflectance to zero the index of refraction must be reduced 25%. Since so little is gained by this reduction and the mechanical strength of the film is lessened, it is not advantageous to reduce the index of the magnesium fluoride.

REFERENCES

(1) **Blodgett, K. B.** Physical Review, 55: 391. 1939.
(2) **Cartwright, C. H.,** and **Turner, A. F.** Physical Review, 55: 675 (A). 1939.
(3) **Jenkins, F. A.,** and **White, H. E.** *Fundamentals of Physical Optics.* McGraw-Hill Co., New York. 1936.
(4) **Jones, F. L.,** and **Homer, H. J.** J. O. S. A., 31: 73. 1941.
(5) **Taylor, H. D.** *The Adjustment and Testing of Telescope Objectives.* T. Cook, York, England. 1892.
(6) **Wood, R. W.** *Physical Optics,* p. 411. Macmillin Co., New York. 1936.

THE PLEISTOCENE GEOLOGY OF THE FOSTORIA QUADRANGLE

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Introduction

The Fostoria Quadrangle, located in northwestern Ohio, lies within the Central Lowland Province of the Interior Plains Major Division (Fennemann, 1916, p. 39). The middle Maumee beach, which represents the final stage of glacial Lake Maumee, trends nearly east-west across the quadrangle through Fostoria and is the dividing line between the Eastern Lake section on the north and the Till Plain section on the south.

Two distinct types of topography are present in the area. North of the middle Maumee beach a lake plain slopes gently northward, the surface of which is interrupted by several low, nearly parallel beach ridges which trend in a general east-west direction. In addition a few, low, bedrock elevations rise above the level of the lake plain. South of the middle Maumee beach there is an extensive till plain with low swells and shallow basins, becoming more pronounced southward as the crest of the Defiance moraine is approached. This moraine which trends east-west across the southern part of the Fostoria quadrangle, breaks the continuity of the till plain. South of the crest of the moraine the till plain continues across the Carey quadrangle.

The entire quadrangle drains to Lake Erie. The eastern or larger part of the quadrangle is drained by tributaries of the Sandusky River. The part of the quadrangle which lies west of the Seneca-Wood and Seneca-Hancock County lines and north of the Defiance moraine is drained by tributaries of the Portage River. A small area of about 27 square miles in the southwest corner of the quadrangle and south of the Defiance moraine drains westward through The Outlet to the Blanchard River and thence to Lake Erie by way of the Auglaize and Maumee Rivers.

Bedrock

Although glacial drift of late Wisconsin age blankets most of the surface, bedrock is exposed in a few places. Good exposures are limited to a few quarries. The bedrock of the area consists of two units both of which belong to the Silurian System.

The lower unit exposed, belongs in the upper part of the Niagaran series and is commonly called Guelph. The Guelph crops out over a wide area in west central Ohio over the crest of the Cincinnati Arch. The Guelph is generally a massive, light gray, rough-textured, porous dolomite. It is highly fossiliferous and contains the following forms in abundance: *Pentamerus oblongus*, *Favosites*, several species, *Megalomus canadensis*, *Trimerella ohioensis*, and reef-like structures of Stromatoporoid material. One of these reefs is well exposed in a small, abandoned quarry in the NW¼ of the SW¼ of Section 29, Liberty Township, Seneca County.

The upper unit is the Greenfield member of the Bass Island formation at the base of the Monroe Division. It overlies the Guelph dolomite, is present on the flanks of the Cincinnati Arch and is exposed in the Fostoria quadrangle at the villages of West Millgrove and Bascom. The Greenfield is a cream colored to drab, fine-grained dolomite commonly in beds from two to six inches in thickness with thin, shaly, carbonaceous partings. The Greenfield fauna includes about a dozen species with *Hindella rostralis* and *Leperditia ohioensis* as the dominant forms (Carman, 1927, p. 487).

It is impossible to place accurately the boundary between the Guelph and the

Greenfield units in the Fostoria quadrangle. Most of the area is underlain by Guelph domolite with Greenfield present in the northwest and the southeast parts. On Fig. 1, the boundary is shown by a broken line where it is delimited to a narrow zone and by a dotted line where it is conjectural.

Glacial Features

DEFIANCE MORAINE

This moraine, first called the Leipsic Ridge (Ohio Geol. Reports, 1871) was later named Defiance (Leverett, 1902, p. 581) from the city of Defiance located on this feature. The Defiance moraine, which trends east-west across the southern part of the Fostoria quadrangle (Fig. 1), and whose crest is at an elevation of 850 to 860 feet above sea-level, is composed mainly of boulder clay, but small amounts of gravel and sand are present locally. An outstanding feature of the moraine is its asymmetrical form, as it rises abruptly from the till plain on the south and descends gently northward. The northern slope of the moraine merges gradually into the till plain so that any boundary proposed is purely arbitrary and does not mark a distinct change in topography. There is a gradual decrease in the intensity of the knobs and basins northward but the difference is one of degree and not of kind.

Leighton and Powers, (1934, pp. 86–87) in their work in Illinois pointed out the need for emphasizing the transition between end moraine and ground moraine of the same glaciation where they are composed of the same material. A brief quotation from their paper follows:

> A terminal moraine and the ground moraine of the same glaciation are by definition gradational and not sharply differentiated. . . . In some regions ground and end moraines are reported to differ in composition, but in this area both are composed almost wholly of boulder clay. The boundary which was necessarily drawn in the field, is based only on topography and is intended as a median line between the low subdued swells of the ground moraine and the higher forms of the till ridge. Its gradational character should be indicated on the published map.

White, (1939, p. 283) points out that the inner part of the Broadway moraine, in central Ohio, is not sharply differentiated from the ground moraine but rather merges gradually into it, and in describing the St. Johns Moraine, formed by the same ice lobe, but lying farther south, White wrote:

> Its inner margin is so poorly marked that the exact width is difficult or impossible to determine. (White, 1939, p. 284.)

On the detailed map of this area (Fig. 1) the belt of subdued knobs and basins, which represents a transition between the well developed knob and basin topography and typical till plain is designated *transition zone.*

The ice front remained in the area now occupied by the Defiance moraine for a considerable length of time, but there were minor periods when ablation was dominant and periods when advance was dominant. This resulted in oscillatory movements of the ice front in the area which is now the narrow, restricted, summit portion of the moraine.

As a result of this alternation of advances and retreats of the ice front, drift was plastered beneath the edge of the ice or pushed forward by the advancing ice to a progressively higher position with each readvance. Later, ablation became dominant over supply and the ice front began retreating to the north. Retreat occurred not by a steady recession but by a series of oscillatory movements in which retreat dominated. This resulted in the formation of the transition zone, which varies from three to five miles in width. Following this the ice front retreated steadily northward beyond the quadrangle. The till plain of the northern portion of the area was soon modified by the waters of glacial lakes, but the strip between the transition zone and middle Maumee beach is unmodified till plain.

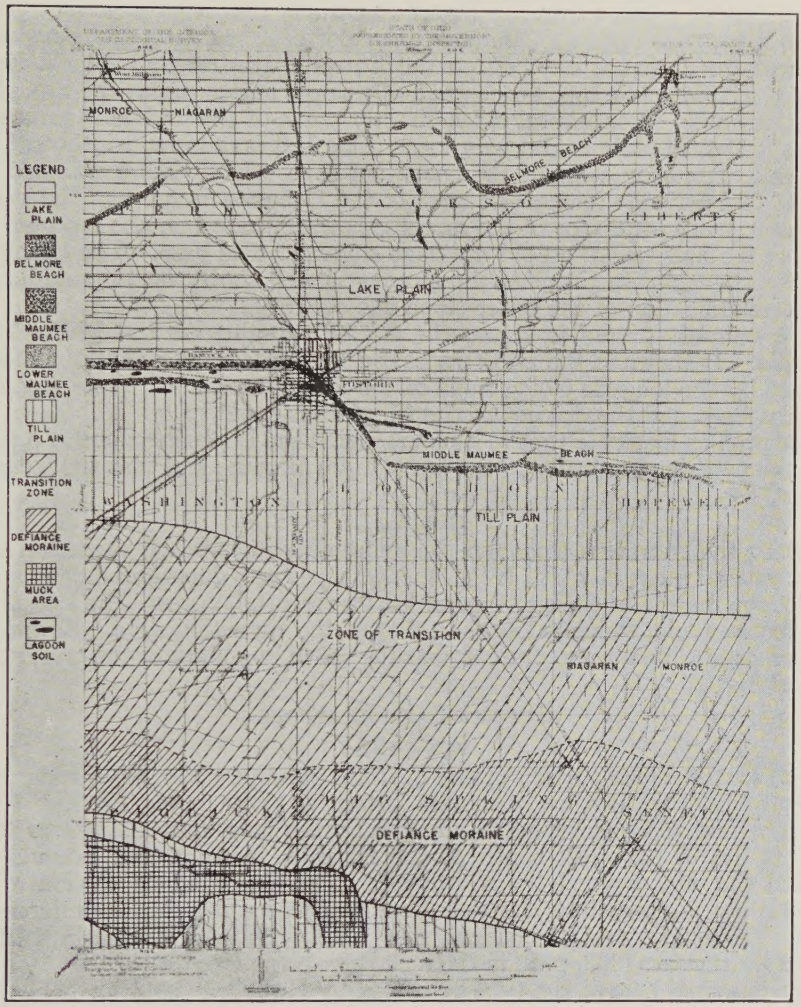

Fig. 1. Glacial map of the Fostoria, Ohio, Quadrangle.

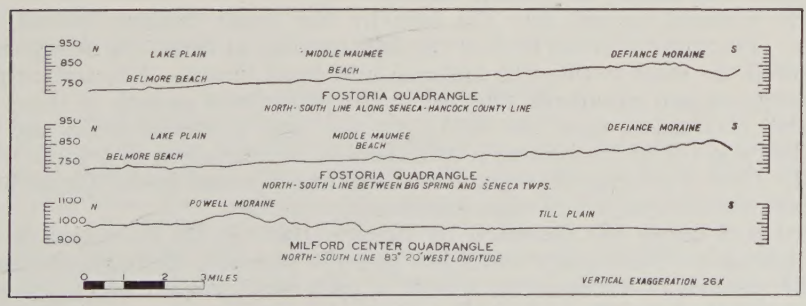

Fig. 2. Three profiles showing the usual asymmetry of terminal moraines in a plains region.

The series of profiles forming Fig. 2 illustrates the usual asymmetry of end moraines in a plains region. The two upper profiles are drawn along north-south lines across the Defiance moraine on the Fostoria quadrangle. The Lake Plain north of the middle Maumee beach gradually slopes northward at the rate of about nine feet per mile. For several miles directly south of the middle Maumee beach the slope of the till plain is also very low. This belt is followed southward by the long, gentle, ice facing slope of the transition zone, which rises southward at the rate of 15 feet per mile toward the crest of the Defiance moraine. The steepness of the outer, southward face of the moraine is accentuated on the topmost profile because of the presence of an old drainage channel at its base. The change from morainic topography to till plain topography is well shown on the middle profile where no modification of the outer slope has occurred.

The lowermost profile is across the Powell moraine on the Milford Center quadrangle. It shows in the northern part a belt of featureless till plain followed southward by the long ice facing slope of the Powell moraine. The outer slope is again very steep and the descent to the till plain is rapid.

These profiles illustrate that in a plains region the ice facing slope of a moraine is a long slope rising gradually to the crest of the moraine and that the outer slope is steeper.

TILL PLAIN

Between the transition zone and the middle Maumee beach there is a strip of till plain several miles in width (Fig. 1). This belt was deposited during a steady retreat of the margin of the continental ice sheet to the north. The slope is eight or nine feet per mile which is less than that of the transition zone. Several other smaller areas of till plain are present near the south boundary of the quadrangle as shown on Fig. 1.

Glacial Lake Features

MUCK AREA

In the southwestern portion of the Fostoria quadrangle in Big Spring and Big Lick townships there is a low, flat area known as "Big Spring Prairie" (Fig. 1). The part within the quadrangle is about six miles long and one to two miles in width. It lies in part just south of the Defiance moraine and extends to the south and the west beyond the quadrangle. The elongated depression in which the prairie lies is down into the rock floor and was a pre-glacial or inter-glacial channel. Tributaries to this channel, now filled with late Wisconsin drift, were described by Bonser (1903, p. 8) in the rock ridge on the south.

A pro-morainal lake of the type described by Hubbard (1915, p. 12) existed in this area from the time of the retreat of the Wisconsin glacier until historic time. When the area was settled the lake basin was gradually drained and is now under cultivation. The history of the lake follows:

Sandy material carried into the lake by the small streams formed deltaic deposits. Fluctuation in the level of the lake exposed at times the sandy material and allowed the wind to pile this material into small dunes. Alternating periods of submergence and emergence resulted in the progressive growth of these dunes. Vegetation encroached upon the lake from the time of its inception and as the plants died and fell to the bottom a considerable accumulation of organic material resulted. Over the dunes the organic material was thin and in the deeper portions of the lake the accumulations were considerably thicker.

A group of dunes was described by Bonser (1903, p. 69) in section 30 of Big Spring township. This sandy condition prevails generally throughout the muck area with patches of dunes at the mouth of each small stream which transported the sand into the lake. Just within the city limits of Carey there are narrow sandy belts in the muck area. Over these sandy belts the muck is only a few inches thick, but becomes progressively thicker in directions transverse to that of the sandy belts. Where sand is absent the muck is underlain with a heavy blue clay.

LAKE PLAIN

North of the middle Maumee beach is a monotonous plain which is a portion of a much more extensive area of lake plain reaching to Lake Erie. The surface is covered with late Wisconsin ground moraine which has been slightly reworked by the waters of the glacial lakes.

Although this portion of the quadrangle is called lake plain there is an absence of any typical lacustrine clays. This has probably resulted from one or both of two conditions: (1) no major streams were bringing material into the lake in this area; or (2) the lake was extremely shallow and any material brought in or worn from the lake floor was carried by the waves and incorporated in the beach ridges or if fine silt was carried out by the undertow and deposited below wave base in deeper water farther north.

GLACIAL LAKE MAUMEE

Lowest Maumee Beach.

Three stages of glacial Lake Maumee are recognized, but only the middle and lowest beaches are present in the Fostoria quadrangle. Throughout northwestern Ohio the lowest beach of Lake Maumee is very poorly developed and fragmentary (Fig. 1) because it was submerged during the formation of the middle beach and was subjected to wave erosion and consequently largely destroyed.

Originally the lowest beach was a well developed and continuous shoreline lying about three miles north of the middle beach, but submergence and subjection to the work of the waves modified the beach until it lost its continuity. The deposits, which now represent the beach, consist of reworked sand and gravel, preserved largely as elongate spits on the landward side of shoal areas, chiefly low rock ridges.

Middle Maumee Beach.

The middle beach of Lake Maumee although about twenty feet higher than the lowest beach was deposited after the formation of the lowest beach when the lower portions of the Imlay outlet were blocked by a readvance of the ice. The beach trends east-west through Fostoria and Bascom at an elevation of 770 to 780 feet above sea-level (Fig. 1). The beach is well developed and is composed of well sorted, cross-bedded, gravel and sand.

This beach enters the quadrangle from the west as a compound beach. The southern or outer beach is poorly developed, but the northern beach is better developed and more complex in structure. Two interpretations may account for the presence of the double ridge: (1) the southern beach may represent a storm ridge built up during periods of high winds; or, (2) the southern ridge may have been the original shoreline and the northern ridge started as an offshore bar in front of it. The presence of highly organic soils between the ridges indicates a lagoon was present, supporting the latter method of development.

GLACIAL LAKE WHITTLESAY

Glacial Lake Whittlesey was named by Taylor (1897, p. 39) in honor of Colonel Charles Whittlesey, one of the early workers on the shorelines of Ohio. Lake Arkona was intermediate in time between Lake Maumee and Lake Whittlesey but it existed at a lower level and is not represented on the Fostoria quadrangle.

The level of Lake Whittlesey was lower than that of any of the stages of Lake Maumee and the outlet was across the thumb region of Michigan. Taylor, 1897, p. 40) originally called the outlet the "Tyre-Ubly outlet" but later used the term "Ubly outlet."

The beach formed by the waters of this lake was called the Belmore beach by Winchell (1873, p. 177) from the village of Belmore, in Putnam County, through which the beach passes.

Belmore Beach.

The Belmore beach, well developed and fairly continuous, trends roughly east-west across the northern part of the quadrangle at an elevation of about 730 feet A. T. (Fig. 1). In the western part, the beach is a ridge of sand and gravel, in places of the dune ridge type. One dune in the SE¼ of the NW¼ of section 21 of Perry township is of the barchan type. The horns of the dune indicate that the prevailing winds were from the northwest.

In the eastern part of the quadrangle near the village of Kansas a well defined, compound, recurved spit is associated with the beach. The spit trends northeast to southwest and the two, long, land-facing termini stand out as elongate, easily visible ridges of sand and gravel. The material is very coarse near Wolf Creek but becomes progressively finer northward.

Summary Statement

The northern portion of the Fostoria quadrangle shows interesting phenomena which are the result of the action of former glacial lakes. Three beaches are present. The southernmost beach is the middle beach of glacial Lake Maumee. The lowest Maumee beach is fragmentary and is represented by elongate spits trending southward from rock knolls. The northernmost beach on the quadrangle is the well developed Belmore beach, the shoreline of glacial Lake Whittlesey. Associated with the Belmore beach just south of the village of Kansas is a well defined, compound recurved spit.

The most prominent feature of the southern half of the quadrangle is the Defiance moraine which trends approximately east-west, passing just south of the village of Alvada. This moraine, whose crest is at an elevation of 850 to 860 feet above sea-level varies from two to five miles in width. An outstanding feature of the moraine is its asymmetrical form, as it rises abruptly from the till plain on the south and descends gently northward. The northern boundary of the moraine is indefinite, and the strong knob and basin topography of the summit portion of the moraine gradually merges into the subdued knobs and basins of the transition zone, which varies from three to five miles in width. North of the transition zone and extending north to the middle Maumee beach is a belt of till plain with a very low slope.

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BIBLIOGRAPHY

1. **Bonser, T. A.** Ecological Studies of Big Spring Prairie. Ohio Acad. Sci., Vol. III, pp. 1–96, 1903.
2. **Carman, J. E.** The Monroe Division of Rocks in Ohio. Journ. Geol., Vol. 35, pp. 481–506, 1927.
3. **Dryer, C. R.** Report on the Geology of Allen County. XIV Ann. Report, Geol. Survey of Indiana, pp. 107–126, 1888.
4. **Fennemann, N. M.** Physical Divisions of the United States. Annals Assoc. American Geographers, Vol. 6, pp. 19–98, 1916.
5. **Hubbard, G. D.** U. S. Geol. Survey Atlas, Columbus Folio (197), 1915.
6. **Leighton, M. M.,** and **Powers, W. E.** Evaluation of Boundaries in the Mapping of Glaciated Areas. Journ. Geol., Vol. 42, pp. 86–87, 1934.
7. **Leverett, Frank.** Glacial Formations and Drainage Features of the Erie and Ohio Basins. U. S. Geol. Survey, Mon. 41, 1902.
8. **Leverett, Frank,** and **Taylor, Frank B.** The Pleistocene of Indiana and Michigan and the History of the Great Lakes. U. S. Geol. Survey, Mon. 53, 1915.
9. ———. Ohio Geological Reports, 1871.
10. **Taylor, F. B.** Correlation of Erie-Huron Beaches with Outlets and Moraines in Southwestern Michigan. Geol. Soc. Am., Vol. 8, 1897.
11. **White, G. W.** End Moraines of North-Central Ohio. Jour. Geol., Vol. 47, pp. 277–289, 1939.
12. **Winchell, N. H.** The Surface Geology of Northwestern Ohio. Proc. Am. Assoc. Adv. Sci., Vol. 21, pp. 152–186, 1873.

A FURTHER NOTE ON THE NITROGEN METABOLISM OF STEREUM GAUSAPATUM FRIES[1]

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In an earlier paper by the senior author (Herrick, 1940), the results of a study of the ability of *S. gausapatum* Fries to utilize nitrogen from various sources were reported. The general conclusion was that this fungus could not obtain nitrogen from inorganic compounds. More recent investigations, which constitute the basis for this paper, make necessary a revision of the earlier conclusion.

The earlier data show that growth on synthetic liquid media containing any one of several inorganic nitrogen compounds or asparagine, as the only source of nitrogen, is not significantly greater than that on a nitrogen free medium. When an equal amount of nitrogen is provided in the form of peptone a luxuriant mycelium is produced.

In the course of some other studies by the authors, it was noticed that the growth of this organism is greatly stimulated by minute amounts of thiamin. Like stimulation of other organisms has been reported in the literature (Addinall, 1940). Following these observations, a careful investigation was undertaken and is reported in the following pages.

EXPERIMENTAL STUDIES

In order to determine the growth promoting effect of thiamin on *S. gausapatum* the following experiment was performed. A synthetic liquid culture medium containing 4.5 gms. of NH_4NO_3 per liter as the only source of nitrogen was prepared. The basic formula for this medium has been previously published (Herrick, 1940). This medium was divided into 50 cc. portions in 200 cc. Erlenmeyer flasks. Thiamin (Merck's Betabion) was dissolved in distilled water, and by dilution a series of concentrations prepared. By the addition of 1 cc. of the appropriate solution to each flask, respectively, culture media were prepared having thiamin content ranging from 10^{-3} to 10^{-10} gms. per flask, respectively. Checks were prepared by the addition of 1 cc. of distilled water, instead of thiamin, to each of several flasks. These flasks were then plugged and autoclaved for 15 minutes at 15 lbs. pressure. Immediately after cooling, each flask was inoculated with a 4 mm. disk cut from a corn-meal-agar petri dish culture of a single spore isolate[2] of *S. gausapatum*. Twenty-eight days after inoculation five cultures from each medium were filtered through each of several previously dried and weighed filter papers. The papers, plus fungous material, were dried at 103° C. for 24 hours and weighed.

The dry weights of fungous mycelium produced on each of the several media are presented in Table 1.

The data presented in Table 1 prove conclusively that this fungus can obtain significant amounts of nitrogen from at least one inorganic compound, and further, the amount of growth is, within certain limits, roughly proportional to the amount of thiamin present. This does not allow us to generalize about the use of nitrogen compounds and so another experiment was devised as follows: Eight liters of a nitrogen-free medium were prepared according to the previously reported formula (Herrick, 1940). This was autoclaved and filtered to dispose of the precipitate.

[1]The writers are greatly indebted to Dr. H. A. Cunningham, Chairman of the Department of Biology, Kent State University, for his cooperation in providing research facilities and encouragement.

[2]The isolate used was "S-12," described in a previous publication (Herrick, 1939).

The original volume was then restored by the addition of distilled water. To one liter portions of this nitrogen-free medium, nitrogen-containing compounds were added so that each contained the same amount of nitrogen as was present in the above experiment using NH_4NO_3. The exact amounts added are shown in the accompanying table (Table 2). Each of these several media was divided into two equal lots. To one portion thiamin was added at the rate of 10^{-4} gms. per 50 cc. The corresponding media without the thiamin served as checks and were the same as those reported in the earlier paper (Herrick, 1940). The media were

TABLE I

THE EFFECT OF THIAMIN ON THE GROWTH OF *S. gausapatum* ON SYNTHETIC LIQUID MEDIA CONTAINING NH_4NO_3 AS THE ONLY SOURCE OF NITROGEN.

Thiamin Content per Flask of 50 cc. of Medium. (Expressed in Grams)	Dry Weight of the Mycelium Produced in Five Flask-Cultures in 28 Days. (Expressed in Grams)
0.001	0.278
0.0001	0.315
0.00001	0.268
0.000001	0.265
0.0000001	0.117
0.00000001	0.157
0.000000001	0.052
0.0000000001	0.045
No Thiamin	0.025
Uninoculated Check	0.011 (Due to precipitate)

TABLE II

THE GROWTH OF *Stereum gausapatum*, USING VARIOUS COMPOUNDS AS A SOURCE OF NITROGEN, WITH AND WITHOUT THIAMIN.

Source of Nitrogen	Amount of Nitrogen Compound per Liter of Medium	Dry Weight of Mycelium Produced in 5 Flask-Cultures in 28 Days. No Thiamin	Dry Weight of Mycelium Produced in 5 Flask-Cultures in 28 Days. Thiamin added
Peptone	10.00 gms.	0.792 gms.	1.439 gms.
Asparagine	7.25 "	0.033 "	0.853 "
NH_4NO_3	4.50 "	0.015 "	0.160 "
NH_4Cl	6.75 "	0.009 "	0.270 "
$(NH_4)_2SO_4$	7.75 "	0.017 "	0.255 "
KNO_3	11.50 "	0.014 "	0.014 "
$NaNO_3$	9.75 "	0.008 "	0.016 "
No Nitrogen		0.013 "	0.011 "

divided into 50 cc. portions in Erlenmeyer flasks, plugged and autoclaved for 15 minutes at 15 lbs. pressure. After cooling, the flasks were uniformly inoculated with 2 mm. disks cut from a vigorously growing corn-meal-agar petri dish culture of the isolate used previously. Twenty-eight days after inoculation five flask-cultures of each medium were filtered through each of several previously dried and weighed filter papers, respectively, and the dry weight of the fungus determined by the method described above.

An examination of the data presented in Table 2 leads to an expansion of the previous conclusion, i. e., that this fungus is able to obtain appreciable quantities of nitrogen, not only from NH_4NO_3 but from NH_4— containing compounds and from asparagine. The —NO_3 ion appears to be of no value to this organism under the conditions of this experiment. In this connection it should be noted that the mycelial growth with NH_4NO_3 is equal to roughly half that produced on media containing NH_4Cl or $(NH_4)_2SO_4$. This is significant since each medium contains the same amount of nitrogen and in the case of NH_4NO_3 about one-half of the nitro-

gen is in the form of $—NO_3$. The nitrogen of asparagine is apparently more readily obtained than that of the $—NH_4$ ion. The ability of thiamin to stimulate growth on peptone medium is of no special interest in the present study but serves as a basis of comparison for the other data.

That K^- and Na^- ions are sometimes toxic is a well known fact. Two lines of evidence indicate that the lack of growth on the KNO_3 and $NaNO_3$ media was not due to such toxicity. First, the addition of peptone to such media enables it to support a heavy growth of mycelium (Herrick, 1940). As a further check, a culture medium was prepared in which there was a balance of antagonistic ions (Miller, 1938, p. 269). The medium had the following composition:

H_2O	1000.0 gms.
Sucrose	50.0 gms.
KH_2PO_4	5.0 gms.
$MgSO_4$	2.5 gms.
$FeCl_2$	0.2 gms.
$NaNO_3$	8.7 gms. (making 0.1 M solution)
KNO_3	22 cc. of a 0.1 M solution
$CaCl_2$	10 cc. of a 0.1 M Solution

This medium was divided into four lots and altered as follows:

1. Nothing added.
2. 10^{-4} gms. of thiamin added per 50 cc.
3. 1% peptone added.
4. 1% peptone plus 10^{-4} gms. thiamin per 50 cc. added.

Five 200 cc. Erlenmeyer flasks, each containing 50 cc. of solution, were prepared with each medium. These were inoculated, allowed to incubate for 28 days, and the dry weight of the mycelium was then obtained. The growth in the two sets containing peptone approximately duplicated the earlier results on peptone-containing medium (Table 2). The growth in the medium containing only $—NO_3$, or $—NO_3$ plus thiamin, as the only source of nitrogen was quite like that normally obtained on nitrogen-free medium. It is therefore concluded that the lack of growth on media containing $—NO_3$ ions as the only source of nitrogen is not due to any toxic effect of Na^- or K^- ions but to the inability of *S. gausapatum* to use the $—NO_3$ ions.

SUMMARY AND CONCLUSIONS

The ability of *Stereum gausapatum* to obtain nitrogen from various sources has been re-investigated.

As reported earlier (Herrick, 1940), synthetic media containing inorganic salts or asparagine as the only source of nitrogen support little or no growth. Peptone-containing medium produces a heavy mycelium. The growth on media containing peptone, asparagine or $—NH_4$ ions, as the only source of nitrogen, is greatly increased by the addition of minute amounts of thiamin. In the case of NH_4NO_3 the growth was found to be roughly proportional to the thiamin content of the medium. The growth on media containing only $—NO_3$ ions as a source of nitrogen was negligible, even though thiamin was present. The lack of growth in such cases was shown not to be due to any toxic effect of cations. This fungus is therefore able to use asparagine and ammonium salts, in addition to peptone, as sources of nitrogen, the thiamin content acting as a limiting factor.

REFERENCES

Addinall, C. R. 1940. The Story of vitamin B_1, revised edition. 72 pp. Merck & Co., Rahway, New Jersey.

Herrick, J. Arthur. 1939. Growth and variability of *Stereum gausapatum* in Culture. Phytopath. 29: 504–511.

1940. The Carbon and nitrogen metabolism of *Stereum gausapatum* Fries. Ohio Journal Sci. 40: 123–129.

Miller, E. C. 1938. Plant physiology. pp. i-xxxi, 1–1201. McGraw-Hill, N. Y.

OCCURRENCE OF POROCEPHALUS CROTALI HUMBOLDT IN FLORIDA

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There has recently been added to the collections of the Museum of Comparative Zoology a long series of Pentastomida collected by Mr. George Nelson in Florida. These were found in the lungs of a very large water Moccasin (*Agkistrodon piscivorus* [Lac.]) from the St. Johns river marsh at Fellsmere, Indian River County, Florida. This snake was the largest of its kind ever seen by Mr. Nelson.

From the fine material that he obtained, numbering 21 specimens (16 ♀ ; 5 ♂) I have had no difficulty in determining the parasites as *Porocephalus crotali* Humboldt by comparison with the descriptions of Miss Hett ('24) and Heymons ('35). Pentastomida are mainly tropical and are far from common in the United States. Just recently Venard and Bangham ('41) have given an account of *Sebekia oxycephala* (Diesing) which occurs in South American crocodiles and alligators, but extends also into the southeastern United States. They found the immature stages in a number of species of Florida fishes, and Holl ('28) had previously reported the same form from fish in North Carolina.

The history of *Porocephalus crotali* goes back almost to the beginning of our knowledge of the Pentastomida. It is antedated only by the accounts of Wrisberg (1765) and others which relate to the European *Linguatula serrata* Frölich that lives as an adult in dogs or more rarely in some other mammals. Porocephalus was first discovered by Alexander von Humboldt during the course of his travels in the American tropics and described by him in 1808 from specimens found in *Crotalus cumanensis* (=*C. terrificus* Laur.). Rudolphi also applied several names to the same form within the next few years and for over a century considerable confusion remained as to the taxonomic status of the species. This matter has been reviewed by Hett ('24) and also less completely by Heymons in his later extensive contribution ('35) on Pentastomida, so that it is unnecessary to repeat it here.

According to Heymons ('35) *Porocephalus crotali* has previously been recorded from four species of rattlesnakes, *Crotalus terrificus* Laur., *C. horridus* Linn., *C. atrox* B. & G., and *C. adamanteus* Pal. The specimens studied by Miss Hett were from the last three snakes mentioned and as these were ones that had been in the Gardens of the London Zoological Society no accurate data on their original provenience is available, although it is probable that they actually came from the southern United States. The record of *C. terrificus* as a host is based on a specimen collected by Heymons, ('35, p. 230) at Butantan, Brazil. Humboldt's original specimens came from Cumaná, Venezuela. I can find no record of the water moccasin as a host after as careful a survey of the literature as I have been able to make, in fact all previous collections have been made from the four species of *Crotalus* mentioned above.

The present note therefore adds another host for this parasite and a definite locality for its occurrence in the United States.

REFERENCES

Hett, Mary L. 1924. On the Family Linguatulidae. Proc. Zool. Soc. London, 1924, Pt. 1, pp. 107–159, 13 figs.

Heymons, R. 1926. Pentastomida. Kükenthal, Handbuch der Zoologie, vol. 3, pp. 69–131, 49 figs.

1935. Pentastomida. Bronns Klassen und Ordnungen des Tierreichs, vol. 4, Abth IV, Buch 1, 268 pp., 148 figs.

Holl, F. J. 1928. A Linguatulid Parasite from North American Fishes. Journ. Parasitol., vol. 15, pp. 63–66.

Humboldt, A. de. 1805–09. Sur un ver intestin trouvé dons le poumon du serpent à sonnettes de Cumaná. Receuil d'observations de zoologie et d'anatomie comparée, pp. 298–303, pl. 26, figs. 1, 2.

Venard, C. E., and **R. V. Bangham.** 1941. *Sebekia oxycephala* (Pentastomida) from Florida Fishes and Some Notes on the Morphology of the Larvae. Ohio Journ. Sci., vol. 41, pp. 23–28, 1 pl.

THE PIT-BUILDING ACTIVITIES OF OHIO ANT-LIONS

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The inverted conical pits built by ant-lions (the larvae of a neuropterous insect identified as *Myrmeleon immaculatus* De Geer) can be found in almost any loose friable soil that is sheltered somewhat from rain and wind. They are common in the soil of cave formations, the author having counted from 25 to 200 of them in such places as Cantwell Cliffs, Rock House, Ash Cave, Jacob's Ladder, or Old Man's Cave. Contradictory accounts of the pit-building behavior and ecology are found in the literature which was reviewed very completely by Wheeler (1930). Excluding the taxonomical studies of this form, very few articles can be found written by American scientists; these are mainly records of incidental observations with the major exception being the laboratory studies by Turner (1915). It is the purpose of the present author to submit field and laboratory data on pit-building with an endeavor to explain some of the discrepancies existing in the literature. He also wishes to take this opportunity to thank W. M. Barrows for his critical suggestions concerning this study.

CONSTRUCTION OF THE PIT

Field Observations. No ant-lions were seen starting the formation of the pits in their natural habitat. Several partial pits were observed in the midst of their construction, and in them the only visible part of the ant-lion was the head with its long mandibles. As the ant-lion moved backwards in an ever-deepening and narrowing circle, the rapid head-tossing movements resulted in many soil particles being thrown over the rim of the pit.

Laboratory Reactions. Several larvae were brought back to the laboratory and placed in individual glass containers that were three and one-half inches in diameter and two and one-half inches deep; these had been filled previously with fine soil and kept in the laboratory room that is maintained at a fairly constant temperature (26 plus or minus 2 degrees Centigrade). When the ant-lion was placed on the soil it soon buried itself beneath the surface by backward locomotion accompanied by downward flexing movements of its abdomen. After a time interval of five to thirty minutes, the digging would begin with the ant-lion moving backwards in a circular path, the tapered posterior tip of its abdomen functioning like a hand-plow and its head and mandibles as a scoop-shovel. The first circular path only approximates the outer boundary of the completed pit, the digging process tending to enlarge it as the larva circles downward. The path traveled by the insect until the completion of the pit can best be described as an inward and downward spiral. Ten out of eighty pits were partial; of these, two were completed later on and the remaining eight were not, but an examination of the remainder a week later showed that the larvae had pupated.

FACTORS GOVERNING THE SIZE OF THE PIT

Field Observations. When the larvae were dug out of the pits it was apparent that with few exceptions the size of the pit varied directly with the size of the ant-lion.

Laboratory Experiments. Twenty-one larvae were weighed, placed in individual containers and left undisturbed for a week. At the end of this time the diameters of the pits were recorded, the larvae removed and examined. Table I shows the results listed as diameter of the pit in millimeters and the weight of the larva in milligrams.

This table shows that the diameter of the pit is in direct proportion to the larval weight between the limits of 21 to 45 mm. It also indicates that any pits larger than this upper limit would contain larvae about to pupate or which have already pupated. Field observations made after this experiment was performed confirmed these conclusions.

TABLE I

Relation of Pit-Diameter to Larval Weight

Individual	Diameter	Weight	Individual	Diameter	Weight
A	21	5	L	33	22
B	21	5	M	33	24
C	22	5	N	40	33
D	22	7	O	43	30
E	24	9	P	48	48*
F	25	11	Q	49	55*
G	26	12	R	50	85*
H	28	13	S	53	63*
I	28	15	T	54	60*
J	29	17	U	55	55*
K	31	20			

*At the time of examination these individuals had pupated.

ECOLOGICAL FACTORS OF PIT-BUILDING

Field Observations. Most accounts state that pit-excavations occur after sundown, during twilight or darkness. Since the author had seen activity during the daytime, it occurred to him that pit-building may be a temperature rather than a light response. Temperature readings were taken in two habitats; Cantwell Cliffs, and Old Man's Cave. Table II lists temperatures and time of day at Cantwell Cliffs' habitat. Readings were taken at three levels of the habitat by placing one thermometer bulb one and one-half inches in the soil which was the usual depth of the ant-lions; a second thermometer was laid on the soil surface, and a third hung with its bulb twelve inches above the soil. The habitat was not exposed to direct sunlight.

TABLE II

Temperature Readings of Cantwell Cliffs' Habitat

Reading Level	Time of Day, June 29, June 30											
	1 p.m.	2 p.m.	3 p.m.	4 p.m.	7 p.m.	8 p.m.	5 a.m.	6 a.m.	7 a.m.	8 a.m.	9 a.m.	12 n.
Above soil	29 C.	26	27	29	25	24	20	20	22	24	26	28
Soil surface	26 C.	25	25	26	25	23½	20½	21	22	23	23½	25½
Below surface	23½	23½	23¼	24	23½	23	21	21	21½	22	22½	23

This table shows that air temperatures are the highest of the three habitat-levels and the variability the greatest. Temperatures on the soil surface are slightly lower and a lesser variability. Temperatures one and a half inches below the surface are the lowest and show the least variability, with only two and one-half degrees difference occurring between the highest and lowest temperatures. The drop in temperatures recorded at two and three P. M. was due to showers which

occurred between one-thirty and two-thirty. A month later temperature readings were taken at Old Man's Cave. While recording temperatures in the morning a far greater number of pits was observed occurring in the shade than in the light, so shade temperatures were taken as well beginning at nine A. M. Table III records these temperatures.

TABLE III

Temperatures of Old Man's Cave Habitat

Reading Level	Time of Day, July 29, July 30										
	9p.m.	10p.m.	11p.m.	1a.m.	3a.m.	5a.m.	7a.m.	9a.m.	11a.m.	1p.m.	5p.m.
Above soil.....	21½	20	19	19	18	18	20	36½	26	25½	26
						.....	Shade	27½	26	25½	25½
Soil surface.....	23	22½	22	21½	20½	20	23	50	33	30	27
							Shade	26	25¼	25	25
Below surface.....	24	24	23½	23	22	21½	22	35	32	29	26
							Shade	24	24	24	24

On the day these temperatures were read the ant-lion habitat was exposed to direct sunlight until nine o'clock. The extreme rises in temperature occurred in the two-hour interval between seven and nine in the morning. After this time the habitat was in the shade. Soil temperatures in the shade showed little variation, with a difference of five degrees on the surface and only two degrees beneath the surface. Soil temperatures in the sun, however, showed a variation of thirty degrees on the surface and thirteen beneath the surface. Since only a few of the pits occurred in the sun-lighted soil as contrasted to the shaded soil, perhaps the high temperatures exceeded the range of tolerance causing death or migration of the ant-lions to shaded soil.

Laboratory Reactions. To test the relationship between temperature and pit-building a thermal gradient was established in a sandbox. This box was about six feet long, a foot in height and width and constructed with wall board. The bottom was lined with copper sheeting, and in each end of the box a copper container twelve inches on a side was attached to this lining. Ice was kept in the one container and an electrical heating unit in the other. Two inches of white sand covered the bottom of the box. Temperature readings of the sand were taken by means of a thermocouple and a thermal gradient recorded between eleven and seventy-four degrees Centigrade. For example, readings taken every ten centimeters from cold to hot were as follows: 11, 18, 23, 25.3, 27.5, 29.5, 32, 36.5, 44, 55, and 74 degrees. In the *first* experiment twenty ant-lions were placed on sand at random throughout the length of the box to determine survival temperatures. They were examined one hour later and those found above 37 degrees were dead while all those in the sand including 37 and below were alive. In the *second* experiment ten larvae were placed on the sand with a temperature of 38.5 degrees and examined twenty-four hours later. Five of them were dead; four of these at the same location that they were placed and the other at 40 degrees. The remaining five had migrated to lower temperatures of 38, 31, 27, 24, and 23.75 degrees as determined by thermocouple measurements. Pits were built by the three at the lowest temperatures but the one at 27 was a partial pit. In the *third* experiment ten larvae were used, spacing them ten centimeters apart throughout the length of the box. Table IV lists the temperatures of the sand at those locations and the results obtained when examined three hours later.

TABLE IV

Relation of Temperature to Activity

Temperature	Results	Temperature	Results
18.3	Partial pit	27.3	Migration to 29.6, no pit
22.0	Partial pit	36.0	Migration to 31.0, no pit
24.9	Pit at 24.8	39.4	Death
26.6	Pit at 26.7	43.2	Death
26.7	Pit at 26.7	50.5	Death

In the *fourth* series of observations a varied number of ant-lions were placed at random in the box as they were brought in the field from time to time. A total of thirty records are summarized in Table V, grouped according to the temperature range in which they were found about six hours after they had been placed on the sand.

TABLE V

Relation of Temperature to Pit Activity

Temperature Range	Number of Larvae	Results
16–18	2	No pits
18–20	1	Small pit
20–22	2	Small pits
22–24	4	Pits
24–26	8	Pits
26–28	8	Pits
28–30	2	No pits
30–32	3	No pits

Although these experiments have involved small numbers and should be repeated, they do indicate that there is a definite relationship between temperature and pit building. Temperatures between 20 and 28 degrees are tolerated; small pits or none are built below this range; migration or death occurs above this range. They indicate that the building of pits after sundown is due to a temperature factor rather than light.

CONCLUSIONS

1. The retrograde circuitous method of pit building is established for this species. Any small or irregular pits found in the field are not caused by a different method, but rather by the presence of small larvae, interrupted activity, or incompletion due to the onset of pupation.

2. The size of the pit varies directly with the size and weight of the larvae until a maximum diameter of 48 mm. and a maximum weight of 45 milligrams is reached. Any diameters or weights larger than the maximum indicate the presence of larvae about to pupate.

3. Pit building occurs only within a temperature range of 20 to 28 degrees; below this range little or no activity takes place; above this range migration occurs; temperatures above 38 degrees may result in the death of the larvae.

4. Field observations show that in direct sunlight soil temperatures may exceed the range of tolerance; this causes migration to either higher temperatures and death, or to lower temperatures and construction of another pit.

REFERENCES

Turner, C. H. 1915. Notes on the behavior of the Ant-Lion. Biol. Bull., 29: 277.
Wheeler, W. M. 1930. Demons of the dust. W. W. Norton and Co., New York.

THE EFFECT OF MUTILATION ON THE TAPEWORM TAENIA TAENIAEFORMIS

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The reader is undoubtedly aware of work which has been done by Child (1910) and others in mutilating certain free-living species of Platyhelminthes. The present report is concerned with the results of experiments which were designed to test the effect of mutilations on a tapeworm. Since the work was started, and while it was in progress, Beaver (1937) has reported the effects of mutilating the fluke *Echinostoma revolutum*. However, as far as we know, there has been no other attempt to test the effect of similar mutilations on the parasitic members of the phylum.

Various types of abnormalities are known to occur in both tapeworms and flukes. In the Cestoda, the polyradiate condition of the body, the abnormal size and peculiar placement of certain prolgottids (i. e., intercalary or supernumerary proglottids) and the condition known as "forked-strobila" are some of the abnormalities which have been reported. In the Trematoda, the reduction or loss of structures, the reversal of organs within members of a species, and the split-body condition are also known to occur.

It is conceivable that some of these abnormalities might be caused by the mutilating effect of the teeth of a host at a time when the latter acquires the parasite. Some types of abnormality occur rarely. This rarity of occurrence is just what one would expect on the basis of chance, since the probability of a tooth penetrating anything as small as a cysticercus is not very great. Moreover, the chance is even more remote that such a tooth would penetrate the right region of a cysticercus, and that such a penetration would only mutilate and still not be great enough to cause the death of the parasite. Again, from observing the feeding habits of some animals, for example a dog, one would not expect the food to be chewed finely. The chance of such an animal biting into a parasite is practically nil, since the food generally does not remain in the mouth long enough to be chewed thoroughly. Moreover, the teeth of some potential hosts seem adapted to grind and crush rather than cut. Such an animal as a frog would not use its teeth for much except to grasp its food during the process of swallowing. However, it must be admitted that mutilation by natural means is possible and that it probably does occur rarely in Nature.

If such natural mutilations occur, it also is apparent that at such times the parasite passes through a critical period in its life cycle. This may result in its death. However, if it recovers, it may either be normal to all appearances, with parts completely regenerated, or it may be modified in size, shape, etc,. due to the effect of the mutilation.

Experiments with Tapeworm Mutilation

The tapeworm which was selected for this series of experiments was the cat tapeworm, *Taenia taeniaeformis* Batsch, 1786. This species was chosen because the bladderworm stage could be easily obtained in numbers from rat hosts, and also because it was large enough to make the necessary mutilation without difficulty.

A number of laboratory rats were heavily infected with the bladderworm stage by feeding them eggs of an adult tapeworm. The bladderworms were allowed to grow in the rats for nine weeks, after which the stages were of sufficient size, with the characteristic chain of proglottids.

It seemed logical to expect any disturbance of the neck of the tapeworm scolex to affect the strobila, since the chain of proglottids of a tapeworm is the result of

transverse budding of the neck region over a period of time. The only part of the scolex mutilated in this series of experiments was the neck region. Since the tapeworm *Taenia taeniaeformis* does not possess a true neck, this term is used here to indicate that region posterior to the suckers from which the proglottids are formed.

In order to accomplish mutilation of the neck without injury to other parts of the head, it was necessary to exert enough pressure on the bladderworm scolex to cause it to evert. This was accomplished by pressing on it with some blunt instrument. Mutilation always consisted in making a dorso-ventral incision through the worm by means of a safety razor blade or a hot platinum wire; thus bisecting the neck. (Fig. 1). This was accomplished under the medium magnification of a stereoscopic type of binocular microscope, and was done just before the stage was to be fed to the cat host.

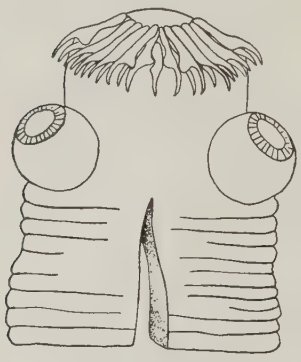

Fig. 1.
Bisection of neck region prior to infection.

Since the cysticercus of *Taenia taeniaeformis* is a proliferating bladderworm, it was necessary to either remove the chain of proglottids prior to bisecting the neck or to bisect both the appended strobila and the neck up to the base of the suckers. When the latter method was employed, the bisection of the strobila started generally at the side of the chain of proglottids. This resulted in a mutilated neck with two strobilae appended to it, one being longer than the other. This difference in size of the two strobilae was hard to avoid, since the movements of a living tapeworm was not conducive to perfect bisection. The effects of such a mutilation are emphasized in the final results obtained for two of the specimens.

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All of the cats used in the experiments were raised from kittens, and were about three-fourths grown at the time they received the parasites. None were infected prior to the time that they were experimentally fed, since each had been segregated in a cage, and had been kept on a controlled diet. Fecal examinations of the hosts from time to time prior to the experimental feeding showed them to be without the tapeworm. Control animals were also kept, none of which were parasitized when examined at autopsy.

Each cat was kept without food for 24 hours prior to the time of feeding it the mutilated bladderworms. The stages were placed in deep pockets cut in beef liver or were wrapped up in small pellets of hamburger. The cats took such food without chewing it, and therefore the mutilation was assured of entrance into the alimentary canal of the host without being altered in any way.

For convenience, the experiments will be grouped under two headings:

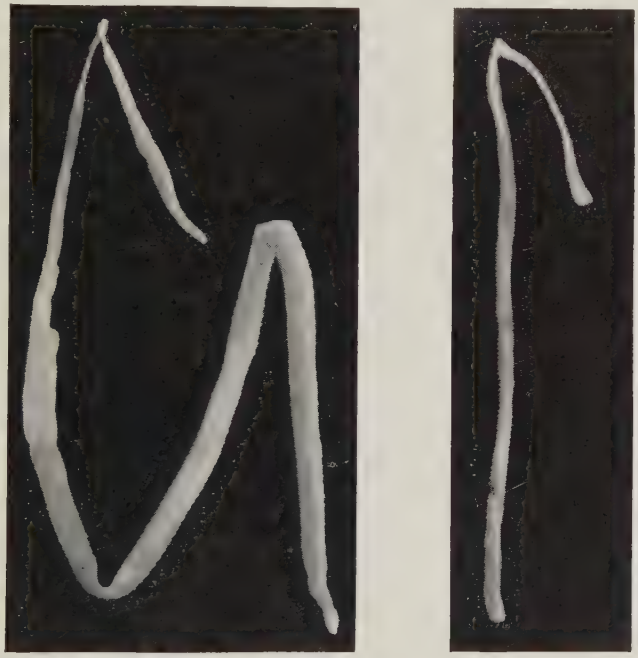
A. Those in which the chain of proglottids was removed from the strobilocercus, so that only the neck region of the scolex was mutilated.

B. Those in which the chain of proglottids was left intact, the mutilation extending through the proglottids as well as the neck of the scolex.

GROUP A

Experiment 1. Four bladderworms were used in the experiment. The chain of proglottids was removed from each, and the neck of the scolex was split longitudinally. The cut, which was made by a razor blade, extended dorso-ventrally and divided the neck region into right and left halves. All four bladderworms were fed to one cat host.

The cat was killed and examined 12 days after the experimental feeding. Two normal tapeworms were recovered from the small intestine. These worms possessed



A B

Fig. 2. Forked strobila: a, 12 days after infection; b, 12 days after infection.

short strobilae, probably due to the fact that they were without strobilae at the time they were fed to the cat. Mutilation in this experiment failed to produce abnormal individuals, regeneration being apparently complete. There was a 50 per cent mortality to the worms in the experiment.

Experiment 2. Four bladderworms were again used in this experiment, and again the chain of proglottids was removed from each. The neck region was split dorso-ventrally into right and left halves by means of a hot razor blade. All four bladderworms were fed to one cat host.

The cat was killed and examined 14 days after the experimental feeding. Two normal tapeworms were recovered. As in the former experiment, these worms possessed only short strobilae. Again, regeneration was apparently complete. There was a 50 per cent mortality to the worms in the experiment.

GROUP B

Experiment 1. Four bladderworms were used in the experiment. The strobila and the neck of each were partially divided dorso-ventrally by means of a hot

platinum wire. The mutilation did not divide the body completely since it extended for only a short distance through the parenchyma from one surface. All four bladderworms were fed to one cat host.

The cat was killed and examined 14 days after the experimental feeding. Only one tapeworm was recovered. This specimen possessed longitudinal indentations which extended the length of the body. However, it appeared normal in all other respects, the only approach to abnormality being the longitudinal striations of the body. There was a 75 per cent mortality to the worms in this experiment.

Experiment 2. Four bladderworms were used in the experiment. The strobila and neck of each were split dorso-ventrally into right and left portions by means of a razor blade. The cut extended anteriorly through the neck to the base of the suckers. All four bladderworms were fed to one cat host.

The cat was killed and examined 12 days after the experimental feeding. One tapeworm was recovered from the small intestine. This specimen was abnormal in that it possessed a forked strobila. (Fig. 2, a). The two strobila started at the neck region, which was also divided, there being no indication of regeneration. It was impossible to determine whether in time the two necks would have grafted together forming one or whether the division would have continued, always forming two strobilae. However, the two necks seemed to be completely healed, which, probably, would have prevented their growing together to form a single neck again. Moreover, since periods of 12 and 14 days from infection were sufficient lengths of time to obtain complete regeneration in the necks of the tapeworms described in Group A, it seems reasonable to expect it to have occurred in the tapeworms of this experiment. The failure to get even a partial regeneration within these time limits suggests that regeneration probably would not have occurred had the tapeworm remained with the host.

There was a 75 per cent mortality to the bladderworms in this experiment.

Experiment 3. Four bladderworms were used in the experiment. Again, the strobila and neck of each were split dorso-ventrally into right and left portions. The division was made with a hot razor blade, and extended anteriorly through the neck to the base of the suckers. All four bladderworms were fed to one cat host.

The cat was killed and examined 12 days after the experimental feeding. One tapeworm was recovered from the small intestine. This specimen was abnormal in that it possessed a forked strobila. (Fig. 2, b). As in the preceding experiment, the proglottids of each strobila had assumed the general shape of normal proglottids, and there was no indication of healing in the neck region. There was a 75 per cent mortality to the bladderworms in this experiment.

An Explanation of the Abnormality Known as Forked-Strobila

There have been a number of cases of forked-strobila of tapeworms reported. The recorded cases up to 1900 have been summarized by Braun (1894–1900).

The abnormal tapeworms recovered in this series of experiments were forked immediately behind the base of the suckers. Examination showed that the scolex, with the exception of the neck region, was normal both in size and structure. The proglottids in the strobilae of both worms had assumed the shape of normal proglottids. These two abnormal tapeworms are somewhat similar, externally, to the case of forked-strobila reported by Chandler (1930) for *Taenia pisiformis* recovered from a dog. Their internal anatomy has not been studied.

The results of the present investigation suggest an explanation for the abnormality known as forked-strobila. It is not suggested that this explanation is necessarily correct for all cases of forked-strobila found in Nature. However, since the condition can be artificially produced by dividing the neck region of the bladderworm scolex, it seems possible that it might occasionally be produced by the teeth of a host animal at the time the latter acquires its infection.

Conclusions

1. The cyst covering of the bladderworm of *Taenia taeniaeformis* is not necessary for successful infection of the definitive host, since bladderworms which have had the cysts removed produce adult worms when fed to the cat.

2. The strobila of the bladderworm of *Taenia taeniaeformis* is not necessary for successful infection of the definitive host, since bladderworms which have had the strobilae removed produce adult worms when fed to the cat.

3. Mutilation of the neck and strobila of the bladderworm of *Taenia taeniaeformis* does not necessarily kill this tapeworm, since cats become infected after ingesting the mutilated bladderworms.

4. The abnormality known as forked-strobila can be produced experimentally in *Taenia taeniaeformis* by dividing the neck and strobila of the bladderworm longitudinally into right and left portions before feeding the stage to the cat host.

5. Mutilating the neck of the bladderworm of *Taenia taeniaeformis* by dividing it longitudinally does not necessarily produce an abnormal tapeworm, since complete regeneration may occur.

6. The production in *Taenia taeniaeformis* of the condition known as forked-strobila by artificial mutilation of the scolex and strobila of the bladderworm suggests that this abnormality may be produced naturally by the teeth of the definitive host at the time the latter acquires its infection.

7. It seems logical to conclude that similar mutilations to other species of tapeworms might produce the condition known as forked-strobila, in as much as this abnormality is known to occur naturally in other species. It also seems logical to expect in some cases a complete regeneration of the mutilated area, resulting in the production of a normal tapeworm.

References

Barker, F. D. 1917. Are the Polyradiate Cestodes Mutations? Anat., Rec., 11: 507–508.

Beaver, P. 1937. Experiments on Regeneration in the Trematode, *Echinostoma revolutum*. Journ. Parasitol., 23: 423–424.

Braun, M. 1894–1900. Vermes, Abt. I b., Cestodes, in Bronn's Klassen u. Ordnungen des Thier-Reichs, Band 4, vii+1731 pp.

Buchanan, J. W. 1922. The Control of Head Formation in Planaria by Means of Anesthetics. Journ. Exp. Zool., 36: 1–47.

Chandler, A. C. 1930. On a Specimen of *Taenia pisiformis* with Completely Double Strobila. Trans. Amer. Micro. Soc., 49: 168–171.

Child, C. M. 1910. Physiological Isolation of Parts and Fission in Planaria. Arch f. Entwickelungsmech. der Organismen., Bd. XXX, 159–205.

Foster, W. D. 1916. Two New Cases of Polyradiate Cestodes, with a Summary of Those Already Known. Journ. Parasitol., 2: 7–19.

Moniez, R. 1890. Sur la Bifurcation Accidentelle que peut Présenter la Chaine des Cestodes et sur les Anneaux dits Surnuméraires. Rev. Biol. du Nord de la France, III, 135–142.

Symposium on Muscle

At the 1940 meeting in New Orleans the American Physiological Society sponsored a symposium on muscle physiology. The papers read at this symposium have been supplemented by several others solicited from investigators not taking part in the symposium to make up the present volume of 15 papers. An introduction has been written by W. O. Fenn. The subjects discussed include: responses of single muscle fibers, conduction in smooth muscle, action potentials of smooth and skeletal muscle, excitability, neuro-muscular transmission, regulation of energy exchange, mechanics of body movements, crystalline pattern of muscle, efferent innervation, diseases of skeletal muscle, and electrolyte equilibrium. A paper on muscle chemistry by Meyerhof is the only European contribution in the volume.—*K. M. Wilbur.*

Biological Synopsia, Vol. III. Muscle, edited by W. O. Fenn. ix+370 pp. Jacques Cattell Press, Lancaster, Pa., 1941. $3.50.

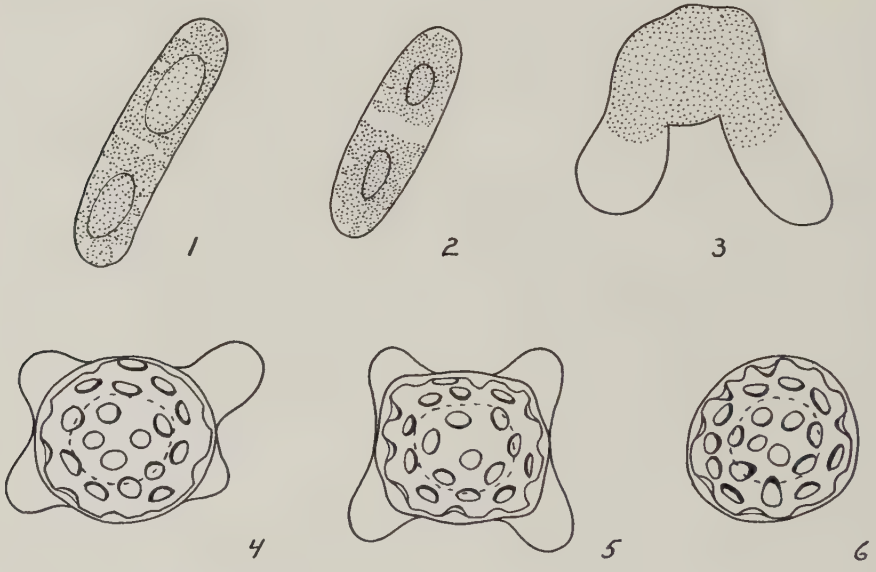
A NEW SPECIES OF CYLINDROCYSTIS[1]

CLARENCE E. TAFT,
Ohio State University

Cylindrocystis splendida n. sp.

Cells cylindrical, slightly curved when old, apices rounded; embedded in a gelatinous matrix. Zygospores globose, ovoid, to quadrate; spore wall of three layers, the outer wall thin and smooth, the median wall thick and pitted, pits 2.5–4.5μ in diameter, the inner wall thin and smooth. Veg. cells 10–11.5μ wide, 23–39μ long; zygospores 20–23μ wide, 23–28μ long.

Cellulis cylindracis, curvatis levitis, apicis orbiculatibus, in gelatis matricis inditis. Zygosporis globosis, ovatis vel quadrationis, mesosporio scrobiculis ornato; ornatis 2.5–4.5μ latis. Cellulis vegetativis 10–11.5μ latis, 23–39μ longioribus; zygosporis 20–23μ latis, 23–28μ longioribus.



Figs. 1, 2. Vegetative Cells.
Fig. 3. Early stage in conjugation.
Figs. 4, 5. Mature spores with remains of conjugating cells.
Fig. 6. A mature spore.

This species is separated from other species of *Cylindrocystis* because of the thick median spore wall with its exceptionally large pits.

Collected and found to be associated with *Mesotaenium aplanosporum* Taft on wet cliffs of the Blackhand Conglomerate Formation, Jackson County, Ohio.

[1]Papers from the Department of Botany, The Ohio State University, No. 442.

STUDIES OF THE GENUS EMPOASCA

(Homoptera, Cicadellidae)

PART IX[1]

Some New Species of Empoasca From Southwestern United States and Mexico

RALPH H. DAVIDSON and DWIGHT M. DeLONG,
Ohio State University

Empoasca chromata n. sp.

Resembling *smaragdula* in coloration but smaller in size and with characteristic internal male genitalia. Length 3 mm.

External characters.—Vertex produced and blunt at apex, about two-thirds as long at middle as basal width between eyes. Color green with a broad black band extending from apex of vertex to tip of clavus. This longitudinal band appears bisected by a pale line on vertex and pronotum in some specimens. On pronotum the band is widened to include two-thirds of the median portion and continues posteriorly including the entire scutellum; the apices of elytra are smoky and the portion between clavus and costa is a darker green. Female last ventral segment roundedly produced on posterior margin.

Internal male genitalia.—Lateral processes rather short, concavely notched on dorsal surface near base, then narrowed to a tapered, pointed apex. Aedeagus with apical third broadened with a blunt process produced forward at base of enlarged portion and apex rounded. Spine of ninth segment long, broad at base, curved sharply ventrally, narrowed to form a long slender tip which is sharp at apex and directed ventrally and slightly anteriorly.

Holotype male, allotype female and one male and five female paratypes collected by Professor and Mrs. J. N. Knull in the Chiracahua Mountains, Arizona, on August 28, 1940. Types in the collections of the authors.

Empoasca omani, n. sp.

Resembling *bidens* and *rubida* in size and coloration, but with characteristic dorsal spine and lateral processes. Length 3 mm.

External characters.—Vertex bluntly produced, about three-fourths as long at middle as basal width between the eyes. Color pale green marked with spots of pale brown. Vertex with a whitish median line, and a whitish spot on each side at front margin, and an oblique white spot near eye on each side at base. Pronotum dull brown with a pale green spot on each humeral angle. Elytra spotted with pale brown. Veins pale, apices smoky. Female last ventral segment roundedly produced.

Internal male genitalia.—Lateral processes long, narrow, and gradually tapered to pointed tips which are directed caudally and dorsally. Aedeagus enlarged at about three-fourths the distance from base, the enlarged portion bent caudally and appearing transverse. A small stubby spine on each side of enlarged portion shows in ventral view. Spine of ninth segment broad at base, narrowed to a rather long slender apical half which extends ventrally and is bifid at apex bearing a posterior tooth and a longer anterior tooth which curves slightly anteriorly.

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[1]Previous parts of this study have appeared as follows: Ohio Jour. Sci. 32: 393–401; 35: 29–39; 36: 225–230; 38: 90–96; 39: 110–118; and Ann. Ent. Soc., 27: 604–609; 33: 608 611; 35: 105–109.

Holotype male and two male paratypes from Tumacacori Mountains, Arizona, (5–15–41) collected by Professor and Mrs. J. N. Knull and deposited in the authors' collections. Allotype female and a series of male and female paratypes from Sabino Canyon, Arizona, (4–23–40) collected by Mr. P. W. Oman and deposited in the U. S. National Museum.

Empoasca omani, var. **iguala,** n. var.

This form is very similar to *omani* in the internal male genital characters but distinctly different in coloration. It is therefore given varietal ranking. Length 3–3.5 mm.

External characters.—Vertex bluntly produced, a little less than two-thirds as long at middle as basal width between the eyes. Color, whitish marked with bright orange-yellow spots. Vertex tinted orange-yellow, with a median line and a spot on each side of front margin and an oblique spot on each side at base, all whitish in color. Pronotum with three whitish anterior spots, and a longitudinal orange-yellow stripe on each side of median line extending across basal angles of scutellum. Elytra pale, subhyaline, marked with orange-yellow spots, apices smoky. Female last ventral segment roundedly produced.

Internal male genitalia.—The lateral processes, aedeagus and spine of ninth segment are similar to those described for *omani*.

Holotype male, allotype female and male and female paratypes from Santa Engracia, Mexico, 11–9–38 (Caldwell); Acapulco Road, Mexico, 11–22–38 (Caldwell); and Iguala, Mexico, 9–11–39 (DeLong); all deposited in the collection of the authors.

Empoasca crocostigmata n. sp.

A spotted species which resembles *amara* in shape of lateral processes. Length 2.5–3 mm.

External characters.—Vertex bluntly produced, lemon-yellow colored, with a median white line and two white spots on each side at front margin and a white spot on each side at base near each eye. Pronotum whitish with two broad longitudinal yellow to reddish stripes which extend across basal angles of scutellum. Scutellum also has a white narrow longitudinal median line and a broader cross-stripe of white. Wings subhyaline, with many spots of orange-red and yellow, apices smoky spotted. Female last ventral segment roundedly produced.

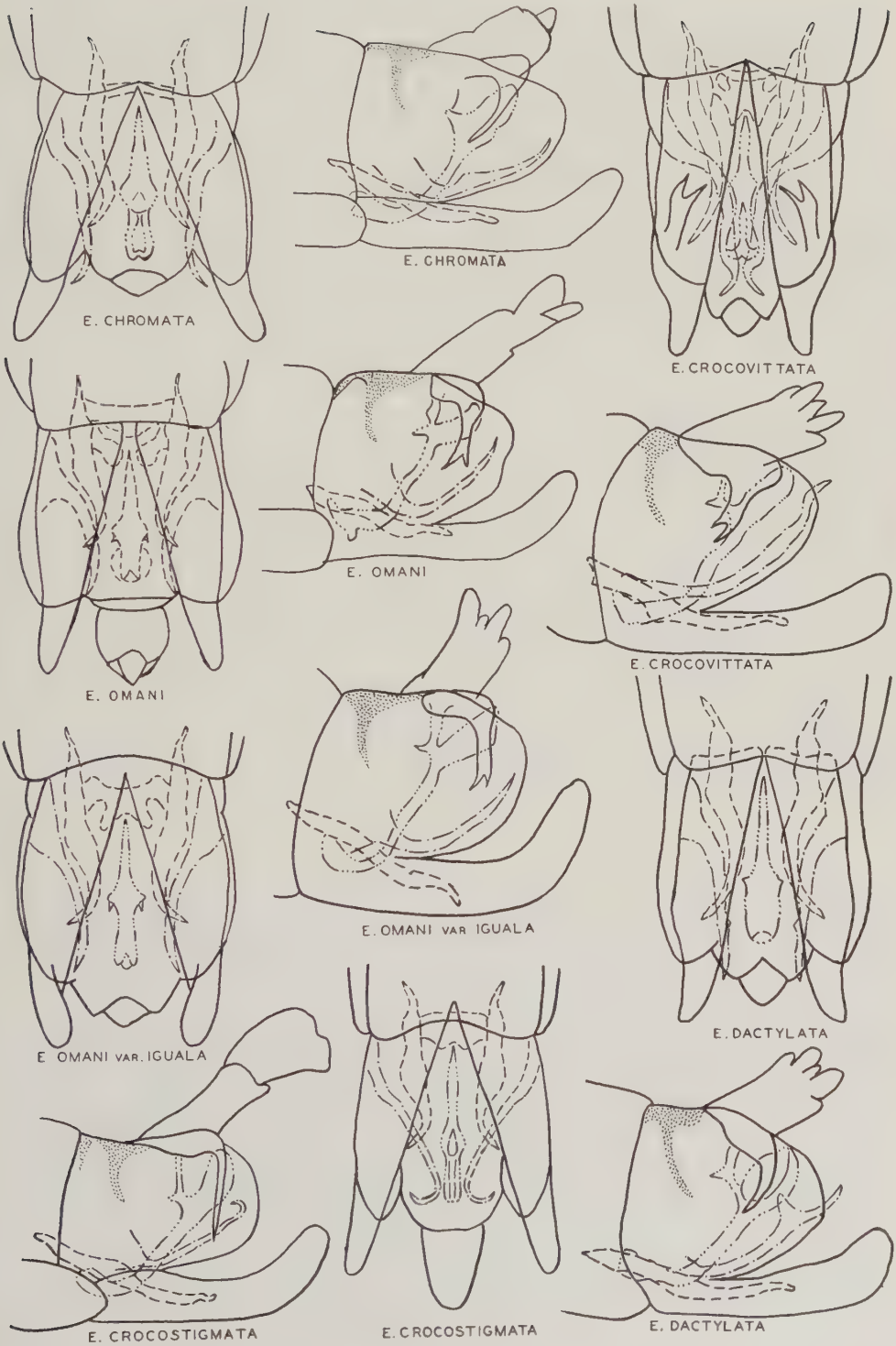
Internal male genitalia.—Lateral processes very narrow, tapered inwardly and upwardly to form pointed tips which are curved outward. Aedeagus enlarged at apical third with a gently rounded apex. Spine of ninth segment rather broad at base, then narrowed abruptly to form a long process tapered to a sharp point which is directed ventrally and slightly anteriorly.

Holotype male, allotype female and male and female paratypes from Monterey, Mexico, November 1, 1938 (Caldwell); also a male paratype from Tamazuncharle, Mexico, November 15, 1938 (Caldwell); and a female paratype from Santa Rita Mountains, Arizona, May 14, 1941 (Knull); all deposited in the collections of the authors.

Empoasca crocovittata, n. sp.

The shape of the head and internal male genitalia seem to place this species in the *alboneura* group. It can be easily identified by the shape of the lateral processes, dorsal spine and coloration. Length 3 mm.

External characters.—Vertex bluntly produced, about one-half as long at middle as basal width between the eyes. Color pale green striped with bright orange. Vertex with a whitish median line; a whitish spot on each side at front margin and a white spot near base next to each eye. Pronotum pale green with three whitish spots along anterior margin and two longitudinal


E. CHROMATA
E. CHROMATA
E. CROCOVITTATA
E. OMANI
E. OMANI
E. CROCOVITTATA
E. OMANI VAR IGUALA
E. OMANI VAR. IGUALA
E. DACTYLATA
E. CROCOSTIGMATA
E. CROCOSTIGMATA
E. DACTYLATA

stripes which extend across basal angles of scutellum. Median part of scutellum very pale green. Wings pale green, subhyaline, with a median dorsal orange stripe and two other similar stripes on each side which are broader, apices smoky. Female last ventral segment roundedly produced.

Internal male genitalia.—Lateral processes long, curving inwardly and upwardly to a slightly enlarged portion near the apex where they bend abruptly outward and taper to pointed tips. Aedeagus with an enlarged apical third and a rounded apex. Spine of ninth segment is broad at base then narrowed at half its length to a bifid apex which is directed slightly anteriorly, the dorsal spine being short and broad and the ventral one long and narrow.

Holotype male from Jiutepec, Morelos, Mexico, September 6, 1939 (DeLong); allotype female from Valles, Mexico, December 1, 1938 (Caldwell); and male and female paratypes from Coatepec, Mexico, August 14, 1934 (Dampf), Acapulco Road, Mexico, November 22, 1938 (Caldwell), and Iguala, Mexico, September 11, 1939 (DeLong) all deposited in the collections of the authors.

Empoasca dactylata, n. sp.

Resembling *alboneura* in size and appearance but with characteristic shape of lateral processes by which the separation can be made. Length 3 mm.

External characters.—Vertex rather broad, produced and rounded, a little more than one-half as long at middle as median width between the eyes at base. Color pale green marked with darker green, wing tips smoky. Vertex with a pair of darker green spots on disc. Pronotum with apical half darker green. Elytra greenish, subhyaline, apices smoky. Female last ventral segment roundedly produced.

Internal male genitalia.—Lateral processes long, enlarged at two-thirds their length, then deeply concave on upper margin to form an anteriorly projecting process and a long slender apical finger process. Aedeagus with an enlarged apical third and a rounded apex. Spine of ninth segment narrowed at more than half its length, apical portion curved ventrally and anteriorly, apex narrow and pointed.

Holotype male, allotype female, and three female paratypes from El Paso County, Texas, collected by Professor and Mrs. J. N. Knull on August 30, 1940, and deposited in the authors collections.

New Paths in Genetics

This book by one of the most widely known of English biologists reviews the trends in three branches of contemporary genetics. The treatment of no subject is intended to be exhaustive, since the book is based upon a series of lectures delivered at the University of Groningen, Holland, in 1940, at which the author intended to emphasize those phases of contemporary genetics with which he has had the widest personal contact.

Genetics is related to biochemistry chiefly by considering cases of plant pigmentation for which both genetic and chemical information are most complete. Other cases, including metabolic disturbances in man, are briefly summarized. The relationship of genetics to development is treated from the standpoint of the effect of various mutant genes upon embryological and histological processes, chiefly in the mouse and rat. No attempt is made to survey the numerous cases of developmental genetics in insects. Greatest space is devoted to the problems of human heredity. By means of examples, the author considers the influences of non-genetic agents such as the mother's age upon the frequency of occurrence of certain abnormalities, the mutation rate of certain human genes, the selective disadvantages of certain others, the importance of detecting and estimating genetic linkage in man, and the importance of understanding the exact mode of action of the so-called modifying genes.

In general the book is intended for the reader with an elementary grounding in genetics, but not with an intimate grasp of all the technical tools.—*E. L. Green.*

New Paths in Genetics, by J. B. S. Haldane. 206 pp. Harper & Brothers, New York and London, 1942. $2.50.

DOUBLE INTEGRAL VARIATION PROBLEMS WITH PRESCRIBED TRANSVERSALITY COEFFICIENTS*

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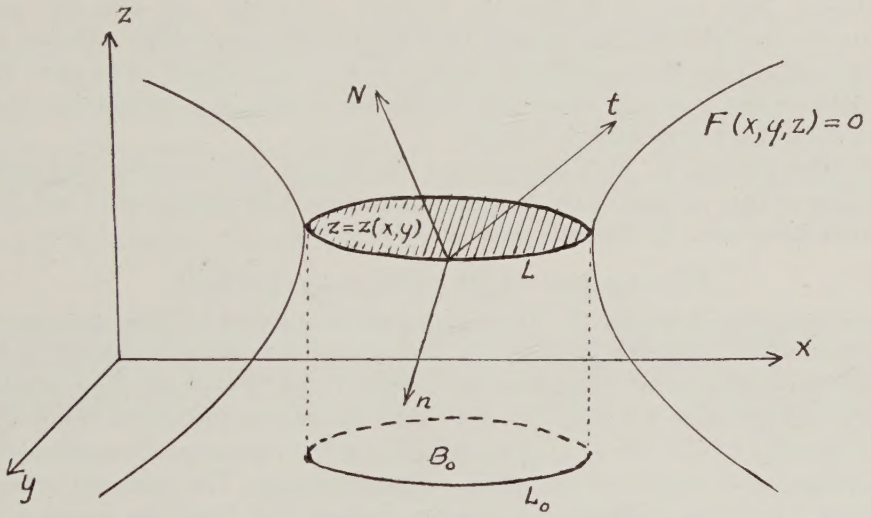
H. A. Simmons has recently published an interesting derivation of the transversality relationship for the variable limit problem of the calculus of variations for n-tuple integrals.[1] It is the purpose of this note to formulate and solve an inverse problem suggested by this transversality relationship. For the sake of perspicuity, attention is confined to the double integral case; but the argument made and the conclusions drawn are easily extended to the general multiple integral considered by Simmons.



Properties of the transversality coefficients of a regular double integral problem.

Consider a double integral

$$(1) \qquad J=\iint_{B_o} f(x, y, z, p, q)\, dx\, dy, \quad z=z(x, y), \quad p=z_x, \quad q=z_y,$$

where f is of class C'' in a region R of sets of (x, y, z, p, q)—values and where the double integration is effected over the closed region B_o (Fig. 1) in the xy-plane bounded by the xy-projection, L_o, of the curve of intersection, L, of the surface $z=z(x, y)$ with a prescribed surface $F(x, y, z)=O$, satisfying certain well known conditions[2] but otherwise arbitrarily chosen. A variable limit problem of the calculus of variations is then to find among surfaces $z=z(x, y)$ of class C'' lying in

*Presented to the American Mathematical Society, April 11, 1941.

[1]H. A. Simmons, *Transactions, American Mathematical Society*, Vol. 36 (1934), pp. 29–43.

[2]In this connection, compare Bolza, *Vorlesungen über Variationsrechnung*, p. 653. Surfaces F = O satisfying the conditions enumerated by Bolza will be referred to as admissible.

the interior of the xyz-projection of R and bounded by their curves of intersection with the surface $F(x, y, z)=0$, one minimizing the integral J.

If $E: z=z(x, y)$ is a surface which furnishes a solution of the problem just formulated, then along L, the curve of intersection of E and $F=0$, a so-called transversality condition of the form

$$f_p F_x+f_q F_y-(f-pf_p-qf_q)F_z=0 \tag{2}$$

must necessarily be satisfied.[3] In particular, if the problem (1) is *regular* in the sense of Hilbert, i. e., if

$$d=\begin{vmatrix} f_{pp} & f_{pq} \\ f_{qp} & f_{qq} \end{vmatrix} \tag{3}$$

is different from zero in R, then the quantity $D=f-pf_p-qf_q$ does not vanish identically; for, if it did, the relation $D\equiv 0$ would lead under differentiation with respect to p and q to the identities $pf_{pp}+qf_{pq}=0$, $pf_{qp}+qf_{qq}=0$ and, as $(p, q)\neq(0, 0)$ the determinant d would, therefore, necessarily vanish in contradiction to our assumption that the problem is regular.

In what follows, we shall assume that the problem (1) is regular and restrict attention to that portion of the fundamental region R in which both f and D are different from zero. In this subregion of R the ratios

$$P'(x, y, z, p, q)=f_p/D; \quad Q'(x, y, z, p, q)=f_q/D, \tag{4}$$

are well defined and of class C'. These ratios will be referred to as the *transversality coefficients* of the variation problem (1). For a regular problem we therefore have defined in every point of L not only the normal $N: (p: q: -1)$ to the minimizing surface and the normal $n: (F_x: F_y: F_z)$ to the transversal surface $F=0$ but also a third direction $t: (P': Q': -1)$ given in terms of the transversality coefficients of the problem and, in view of (2), always orthogonal to n. The existence of such a direction t of course implies a relationship between the directions n and N; for example, if $f=(1+p^2+q^2)^{1/2}$ then it is found that t is N and hence $t\perp n$ implies $N\perp n$, i. e., for the problem of minimizing the area integral, the surfaces E and $F=0$ must necessarily intersect under a right angle.

By inspection, $1+pP'+qQ'=f/D$. Hence, in the subregion of R under consideration, the transversality coefficients necessarily satisfy the inequality

$$1+pP'+qQ'\neq 0. \tag{5}$$

Geometrically, this inequation means that the normal N to the extremal surface through the point (x, y, z) does not lie in the plane with normal t passing through this point. Furthermore, it is easy to verify that

$$|\,\partial(P', Q')/\partial(p, q)\,| = fd/D^3. \tag{6}$$

Consequently, in the specified subregion of R, the Jacobian of the transversality coefficients with respect to p and q is necessarily different from zero.

[3] See, for example, H. A. Simmons, *Transactions, American Mathematical Society*, Vol. 28 (1926), pp. 235–251.

Variation Problems with prescribed transversality coefficients.

Suppose now that a pair of functions $P(x, y, z, p, q)$, $Q(x, y, z, p, q)$ of class C' and satisfying the inequalities $1+pP+qQ\neq 0$, $|\partial(P, Q)/\partial(p, q)|\neq 0$ in a region S of (x, y, z, p, q)—values is given. It is natural to inquire if there always exists a regular problem in S of which the given functions P, Q are the transversality coefficients. To answer this question we return to the transversality relation (2) and observe that for a definite but arbitrarily chosen admissible surface $F=0$, this condition established a certain relationship between the elements (x, y, z, p, q) and (x, y, z, F_x, F_y, F_z), that is to say, between the surface element (x, y, z, p, q) and the plane of directions $dx : dy : dz$ with normal n. Hence, if the given functions P, Q are to be the transversality coefficients of a problem (1) the equations

$$PF_x+QF_y-F_z=0 \tag{7}$$

and (2) must establish the same relation between surface elements (x, y, z, p, q) and planes with normal n for every admissible choice of $F=0$. This can only be true if P and Q are such that every admissible choice of $F=0$ for which the left member of (2) vanishes, also makes the left member of (7) vanish and conversely. But then corresponding coefficients in these two relations must be proportional. Consequently, a pair of functions, P, Q as described can be the transversality coefficients of a regular problem (1) if, and only if, there exists a function $f(x, y, z, p, q)$ satisfying the relations

$$f-pf_p-qf_q=h, \quad f_p=hP, \quad f_q=hQ, \tag{8}$$

where $h\neq 0$ is a function of x, y, z, p, q. Elimination of h in (8) leads to the following system of non-homogeneous partial differential equations which must be satisfied by f regarded as a function of the independent variables p, q and the parameters x, y, z,

$$\begin{aligned} Pf-(1+pP)f_p-qPf_q &=0, \\ Qf-pQf_p-(1+qQ)f_q &=0. \end{aligned} \tag{9}$$

To ascertain the integrability conditions for the system (9), we transform it into a system of equations linear and homogeneous in the first partial derivatives of a function $g(x, y, z, p, q, f)$ with $g_f\neq 0$, so that when g is known, f is determined by means of the equation $g=$constant. The resulting system is

$$\begin{aligned} U_1g=(1+pP)g_p+ \quad qPg_q+fPg_f=0, \\ U_2g= \quad pQg_p+(1+qQ)g_q+fQg_f=0. \end{aligned} \tag{10}$$

The equations (10) are obviously independent since the matrix of coefficients contains a second order determinant with the value $1+pP+qQ$ and, therefore, by hypothesis different from zero. Hence if the commutator $(U_1, U_2)g$ of this pair of equations is not a linear combination of U_1g and U_2g, the only solution for g is a constant and, therefore, a function f as required in (8) does not exist. It is easily shown that a necessary and sufficient condition for $(U_1, U_2)g$ to be a linear combination of the left members of the original equations is that P and Q satisfy the relation $C=0$, where

$$C = p(PQ_p - QP_p) + q(PQ_q - QP_q) + (Q_p - P_q). \tag{11}$$

The results so far obtained may be summarized in the following theorem:

THEOREM 1. *Necessary and sufficient conditions for a pair of functions* $P(x, y, z, p, q)$, $Q(x, y, z, p, q)$ *to be the transversality coefficients of a regular problem* (1) *in a region* S *of* (x, y, z, p, q)*—values are that in* S *the functions* P, Q *be of class* C' *and satisfy the inequalities* $1+pP+qQ \neq 0$, $\left| \partial(P, Q)/\partial(p, q) \right| \neq 0$ and the relation $C=0$.

We shall refer to a pair of functions P, Q satisfying the conditions enumerated in Theorem 1 as an admissible pair of functions. Suppose now that an admissible pair of functions is prescribed. Our next problem is to determine the most general integrand function $f(x, y, z, p, q)$ of a regular problem (1) having this pair as its transversality coefficients. To solve this problem we introduce the line integral

$$K = \int_{0,0}^{p,q} (P\,dp + Q\,dq)/(1+pP+qQ). \tag{12}$$

A necessary condition for this line integral to be independent of the path of integration is that $c=0$, where

$$c = (\partial/\partial q)[P/(1+pP+qQ)] - (\partial/\partial p)[Q/(1+pP+qQ)]. \tag{13}$$

This condition is also a sufficient condition for independence of path in a space of suitably simple connectivity properties. Since it is easy to show that $c=C$, it follows that when $C=0$, as it does for the pair P, Q under consideration, the line integral K is independent of the path in such a space.

A particular solution of the homogeneous system (10) is given by the function

$$g(x, y, z, p, q, f) = f.e^{-K(x, y, z, p, q)}, \tag{14}$$

and, therefore, since the general integral of a complete system of two equations in three independent variables is an arbitrary function of a single particular integral of the system, the most general solution of (10) is given by

$$g = A(f.e^{-K}, x, y, z) \tag{15}$$

where A is the symbol of an arbitrary function. The most general non-singular solution f of (9) is now obtained by solving for f the relation $A=0$. Whence

THEOREM 2. *If a pair of functions* P(x, y, x, p, q), Q(x, y, z, p, q) *satisfy the conditions of Theorem 1, the most general regular problem* (1) *for which the functions* P, Q *are the transversality coefficients has an integrand function*

$$f(x, y, z, p, q) = a(x, y, z).e^{K} \tag{16}$$

where a *is different from zero and of class* C'' *but is otherwise an arbitrary function of its arguments and where* K *has the value* (12).